Coastal and Submesoscale Process Studies for ASIRI

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LONG-TERM GOALS

To determine the role of upper ocean processes, including mixing and advection, on freshwater dispersal, sea surface temperature, density structure, and air-sea heat fluxes, with the objective of understanding ocean's contribution to variability of the monsoons on intra-seasonal time scales in the Bay of Bengal.

OBJECTIVES

We will conduct process studies to examine and evaluate lateral and vertical routes for dispersal of the freshwater in the Bay of Bengal. The freshwater affects the vertical density structure (stratification) and thereby vertical mixing of heat. We will ascertain the factors that control sea surface temperature. Spectrally resolved light will be measured over depth to estimate the wavelength-dependent attenuation. This will be related to the inherent optical properties (scattering and absorption) also to be measured.

APPROACH

We propose evaluating the one-dimensional balance at the RAMA mooring at 15N to ascertain whether three dimensional processes are important. We will also use the existing ARGO profiles to get an idea of the horizontal buoyancy gradients in the Bay of Bengal. These would be useful for process experiments.

Several numerical experiments over a range of scales are outlined as follows:

i. With strong surface freshwater stratification and a barrier layer, forced by winds, and with mixing modeled by a dynamic subgrid closure scheme to examine the vertical mixing in response to surface forcing.

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ii. With a coastal buoyant current against steep topography, forced by winds, to examine the instabilities of the current in response to wind-driven up-/down-welling.

iii. With a wind stress curl to generate a cold upwelling feature to examine the stability of the cold dome.

iv. With high resolution winds that resolve the near-inertial motion and a diurnal heat flux. This would ascertain whether the near-inertial mixing is important and rectification effects can change the mixed layer structure.

v. Offshore mesoscale eddies interacting with the coastal current

On the cruise in November-December 2013 (leg 2), we will deploy a radiometer and a bioptical profiling package that will measure downwelling solar irradiance and inherent optical properties in the upper 150 meters of the water column. We plan to profile with every CTD profile (about 60-70 profiles on Leg 2 spaced at about 30 km).

PRELIMINARY RESULTS

Manita Chouksey, a summer intern MTech student from IIT BBS India visited Tandon's laboratory in summer 2013 and worked with him on data from 15N RAMA mooring. Using the COARE3.0 algorithms to construct air-sea fluxes, and using PWP mixed layer model, the results show that model characteristics begin to diverge from the data, and beyond a few days, advective processes become important at this location. Manita is now focusing on the effect of optical characteristics on the upper ocean modeling.

Postdoc Dr. Sanjiv Ramachandran and the PIs analyzed depth-averaged lateral gradients in the bay using Argo profiles for the months of October, November and December. We chose two regions for the analysis, one in the open ocean (88-90E, 9-12N) and one closer to the coast (87-92E, 15-18N). The lateral gradients increase with decreasing scale (Fig.1) for all three months, from $O(10^{-8}\ s^{-2})$ at scales O(100km) to $O(10^{-6}\ s^{-2})$ at scales O(1-10km). This is true for the gradients averaged two different depth ranges, 0-20m and 20-100m. At smaller scales (O(1-10km)) the gradients in the region close to the coast typically tend to exceed those in the open ocean. The large lateral gradients in the upper ocean strongly suggest O(1—10km) submesoscale frontal processes may be important in the North Bay. Such processes have been found to be vital to the upper-ocean dynamics in the North Atlantic and the Kuroshio. Compared to these regions, our estimated values of the lateral gradients in the upper 20m are significantly larger, hinting potentially at an even greater role for submesoscale physics in the coastal BoB. The baroclinicity at depth (100m) could give rise to coupling between the fast submesoscale modes in the upper ocean and the slower mesoscale dynamics below.

The T-S structure for these months (Fig.2) shows the formation of a temperature inversion by December, probably due to the creation of a barrier layer. The inversion gets stronger as we approach the coast. Another interesting feature revealed in the T-S diagram is the presence of compensating gradients in December, clearer in the top panel of Fig. 2. The large influx of freshwater from river run-off into the bay creates strong gradients in the salinity field, and consequently, the buoyancy field. Such gradients, however, can be erased rapidly on inertial time scales by frontal, submesoscale processes, which are efficient in converting the available potential energy residing in the lateral gradient to kinetic energy.

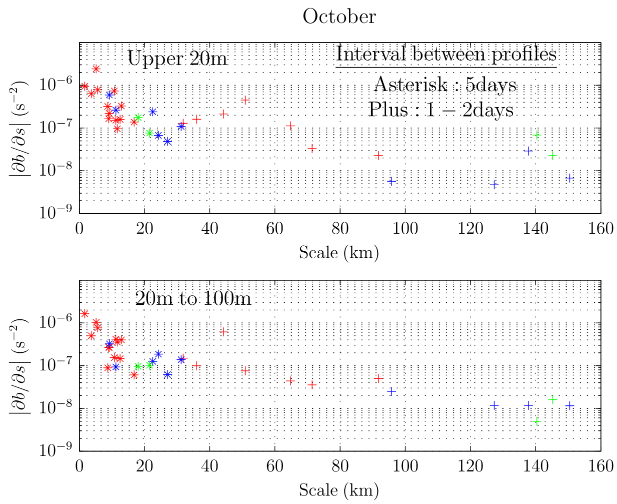

Figure 1 Lateral buoyancy gradient versus scale based on Argo float profiles within 1-2 days and within 5 days. The buoyancy gradients are very significant at scales of less than 30km in the upper 100m.

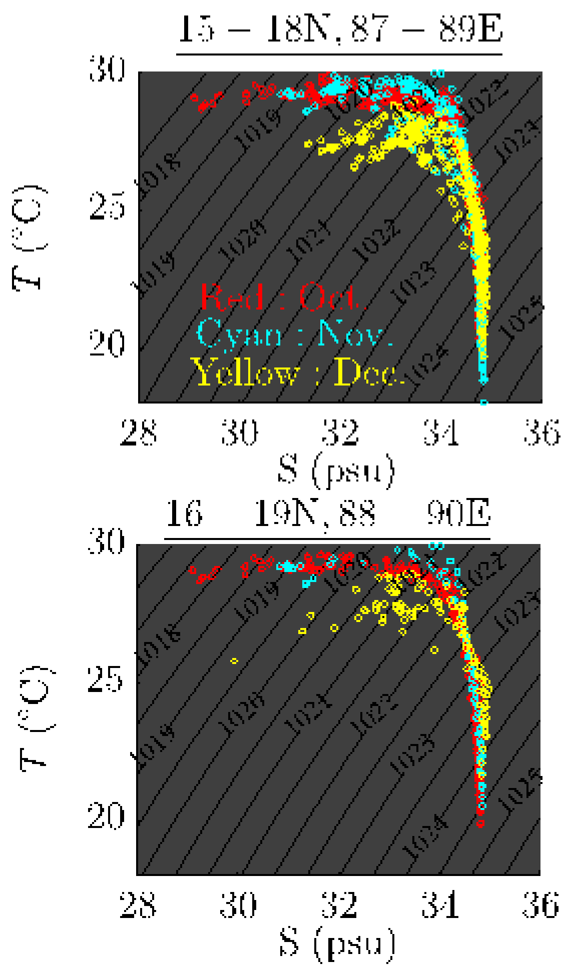

Figure 2 T-S structure in selected region of the Bay based on ARGO float profiles, showing temperature inversion in December profiles (barrier layer) and compensated gradients.

Our Process Study Ocean Model is run with characteristic density profiles from 18N and 15N separated by a front. The model is forced with high frequency winds. The shallow fresh water layer is found to respond strongly to the wind. Ekman fluxes change direction causing the surface freshwater layer to be pushed from one direction to another (Fig. 3).

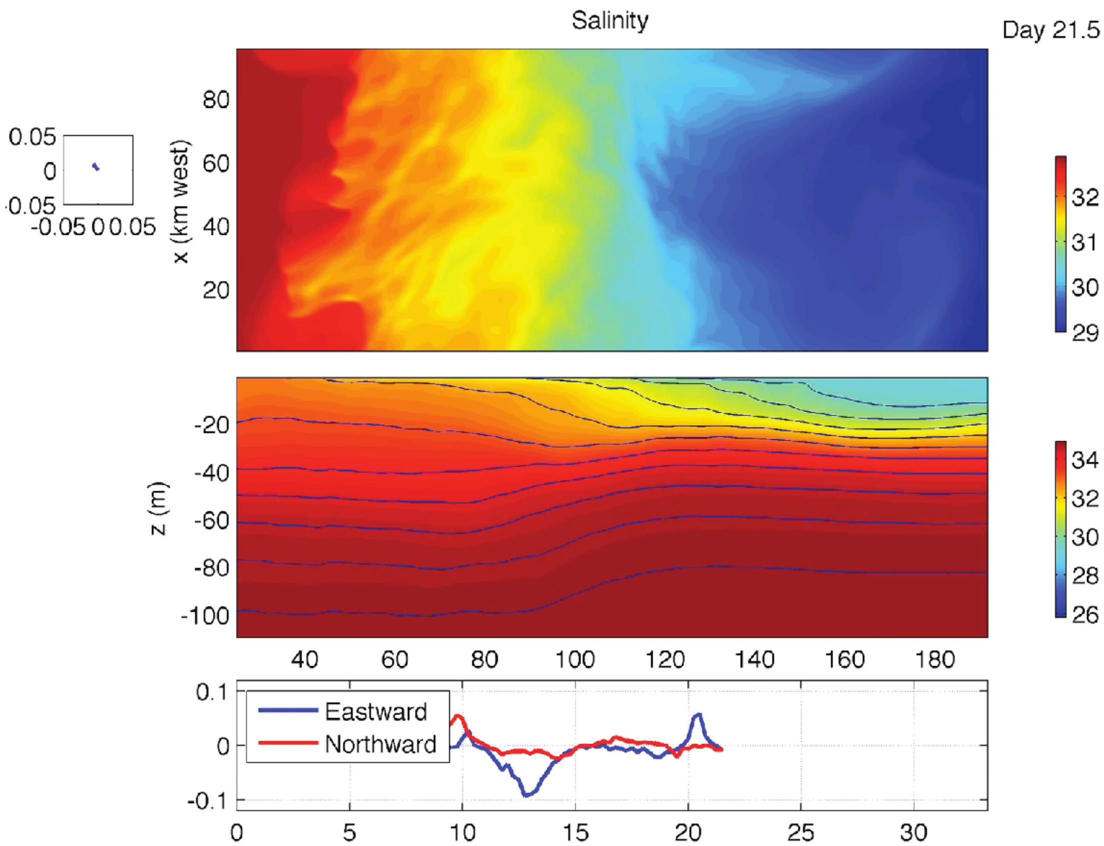

Figure 3. Salinity from our model. Top row - Surface salinity, middle row – vertical section, and third row – wind stress applied during the expiment.